

Final Technical Report

ANALYSIS OF USArray DATA TO SURVEY INDUCED EARTHQUAKES IN THE EAGLE FORD SHALE OF TEXAS AND THE BAKKEN SHALE OF NORTH DAKOTA

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1 ABSTRACT

This research project evaluated seismicity in two geographic regions, the Eagle Ford of Texas and the Williston Basin of North Dakota, hoping to identify earthquakes that may have been induced or triggered by human activity related to fluid injection or petroleum production. In each region the primary approach was to analyze data collected by temporary seismographs that have operated for two years and were installed as part of the National Science Foundation's USArray Transportable Array program. I anticipated that, as in our previous research concerning earthquakes in the Fort Worth Basin (*Frohlich et al.*, 2011; 2012), most Eagle Ford and Williston Basin earthquakes would occur in clusters associated with (within ~3 km of) high-volume (maximum injection rates > 150,000 BWPM) injection disposal wells. Instead, during the time periods analyzed (2008-2011) I found that:

- (1) Most Eagle Ford earthquakes occurred following significance increases in fluid (water plus oil) production (not injection; see *Frohlich and Brunt*, 2013; 2014);
- (2) In the Williston Basin almost no earthquakes occurred in spite of significant injection and production activity (see *Frohlich et al.*, 2015b).

Thus, an unanticipated result of this research project was that the geographic regions investigated were unlike the Fort Worth Basin; i.e., in these regions, when earthquakes were identified, if at all, they seldom seemed to be associated with high-volume injection.

2. OTHER INVESTIGATIONS UNDERTAKEN

In this report I will not further describe the results summarized in the abstract, as these results are all now available as publications in the peer-reviewed literature.

However, in addition to carrying out the proposed research in the Eagle Ford and Williston Basin, a second specified objective of this project was to identify geographic regions, individual oil and gas fields, or particular seismic sequences appropriate for more intensive study, and to assess what will be required to obtain and analyze the data for each. Three such regions/sequences have been identified. While all three of these situations require additional research attention, various coauthors and I did manage to publish preliminary results:

- (1) In western Texas south of the Panhandle, an M4.3 earthquake occurred 11 September 2011 near the town of Snyder and apparently within the Cogdell petroleum field. *Gan and Frohlich* (2013) evaluated Cogdell earthquakes between 2006-2011 that led up to this event, and concluded they occurred near wells injecting significant amounts of gas (not water);
- (2) In east Texas an M4.8 earthquake occurred on 17 May 2012 near the town of Timpson, Texas; with assistance from colleagues at the U.S. Geological survey, Stephen F. Austin State University, and Eagle Pass High School, we determined this earthquake and its aftershocks occurred near two high-volume injection wells, at or below the depth of injection (*Frohlich et al.*, 2014).
- (3) While studying the Williston Basin, I noticed that many kinds of earthquakes (some possibly induced) and other seismic sources (mostly mining explosions), occurred in Wyoming, I identified two peculiarly deep (~75 km) events, unlike any well-located earthquakes occurring heretofore in the U.S. (see *Frohlich et al.*, 2015a).

In response to the 2014 U.S.G.S. Earthquake Hazards Program announcement G14AS00036, a colleague (Jake Walter) and I proposed to undertake a more thorough assessment of possibly induced earthquakes in the Texas Panhandle and in Wyoming. This proposed research was not recommended for funding. However, Walter and I anticipate resubmitting a revised proposal to the Earthquake Hazards Program in 2015.

Finally, various colleagues and I participated in three other projects that concern induced seismicity:

- (1) In a project led by Peter Eichhubl and Julia Gale of the University of Texas Bureau of Economic Geology, we are using the ABAQUS program to model fluid flow and fault stress in the regions surrounding the 17 May 2012 Timpson earthquake. A publication describing this is in draft form.
- (2) In a project led by colleagues at Southern Methodist University (Matt Hornbach, Heather DeShon, Brian Stump, Chris Hayward) but including U.S.G.S and University

of Texas Petroleum Engineering colleagues, we are investigating the Azle, Texas earthquake sequence and modeling regional fluid flow and fault stress (see *Hornbach et al.*, 2015).

(3) In a project conceived by the SMU colleagues mentioned above and SMU graduate student Ashley Justinic, we located and evaluated apparently-induced seismicity near Cleburne, TX (*Justinic et al.*, 2013).

3. BIBLIOGRAPHY OF PUBLICATIONS ACKNOWLEDGING AWARD G13AP200023

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4. OTHER PUBLICATIONS CITED

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